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GEO-ELECTRICAL MEASUREMENTS IN ENVIRONMENT WITH PRESENCE OF UNDERGROUND WATER

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A b s t r a c t: The coal mine "Suvodol" is chosen for geo-electrical examination because it has been most thoroughly researched and has the densest network of mapped boreholes. Through examination of the parameters from the boreholes and the geological map of the coal mine we determinate the layered structure of the ore body that provides favorable conditions for applying the method of geo-electrical sounding. In the process of production of the models particular attention is given to the level of underground water that has dominant influence in the conductivity properties of the geological structures.The curves of apparent electrical resistance are interpreted while solving the direct task. For acquiring precise and concrete data while interpreting the synthetic curves it is important to obtain accurate data for the mapped geological material.

Key words: geo-electrical investigations; geo-electrical sounding; apparent electrical resistance

INTRODUCTION

In order to obtain precise and concrete results of the researched environment when using geophysical methods, it is necessary to determine the appropriate method depending on field conditions, geological features of the environment and the purpose of the investigations. Field conditions in mines and coal deposits allow obtaining precise results when applying geophysical investigations with the usage of the geo-electrical methods. The geo-electrical methods are based on conduction of electricity in rock masses and recording the electrical resistance that they manifest [1].

While analyzing and processing the data from the geological map of the investigated area we can conclude that the ore body in the surrounding is composed of typical rock masses with different real electrical resistance. Because the differences in the real electrical resistance of the geological structures are large enough to be recorded, analyzed and on their basis identified, the usage of the geo-electrical methods is quite reasonable and logical solution [2]. When analyzing the data obtained from mapped boreholes in the research area we conclude that the ore body is horizontally layered. Because of such layering of the ore body the most suitable geo-electrical method to use is the method of geo-electrical sounding. The level of underground water significantly effects the data that are obtained through geo-electrical investigations. According to that for successful application of the geo-electrical investigations it is important to determinate the level of the underground water as well as its influence on the conductivity properties of the geological environments [3].

The investigated area is chosen from the current map situation in the coal mine "Suvodol", in distinctive geological environment with higher levels of groundwater where there is construction of drainage and controlling system of the level of underground water [4]. The drainage system is composed of a series of wells and piezometers serving in two different routes across a semicircular line, both with different number of wells and piezometers. All data which can be obtained for the experimental environment are in favor of detailed design and drafting system.

The analysis of the mapped boreholes shows that the investigated area is mostly built from:

– gneiss – the main plate of the basin,
– sands with different granularity,
– composition of clay and sand,
– sands with organic materials,
– coal as a mineral resource,

RESEARCH AREA

The examined area is presented as one profile line processed that extends across the five boreholes: 49 / 52–49 / 56–49 / 60–49 / 64–49 / 68. The boreholes have different depth that varies in the range of 107.4 m to 159 m [5]. The distance between each borehole is 200 m hence, the profiled area has a length of 800 m.

The profile line goes directly thorough the drainage system that is already made and starts before the first well and ends after the last made well in the system [6]. All constructed wells in the system have been tested for verifying the level of underground water for each well on day 21. 8. 2012 [7]. Using that data the geological profile for the first profile line is not going to show just the geological features of the examined area. In addition the geological profile presents the wells their position on the surface area, depth as well as the level of underground water [8]. On Figure 1 the registered depth of underground water for each well is shown with red lines and unit of measurement that represents the depth of the water. All the depths are connected with blue line that represents the level of underground water through the profile line.

The geological profile is made with the usage of the data obtained from the mapped boreholes and the field trials made on the drainage system. In the Figure 1 is presented the geological profile of the investigated area.

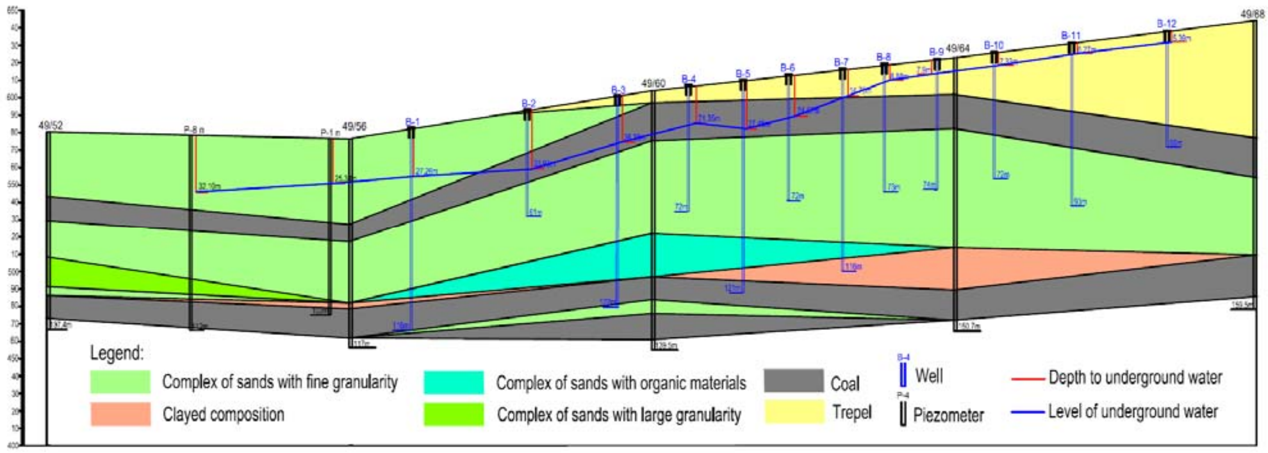

Fig. 1. Geological profile of the investigated area

GEO-ELECTRICAL PROPERTIES OF THE GEOLOGICAL STRUCTURES

For successful application of the geo-electrical method of sounding, despite the geological data it is important to determinate the conductivity properties of the geological environments or the values of the real electrical resistance. The data for the real electrical resistance is gained by registering the electrical resistance while inducing a known electrical field in the geological structures. The values of the real electrical resistance can vary and reach from 10 to 10^7 Ωm, and manly depends from structure and the geo-mechanical parameters of the structures as well as the level of underground water if present [9]. In the Table 1 are shown the structurally different geological environments with the real electrical resistance that they manifest [10].

T a b l e 1

Conductivity properties of the geological environments

Geological structures	Real electrical resistance (Ωm)
Complex of sands with fine granularity	200
Clayed composition	20
Complex of sand with organic materials	150
Complex of sands with large granularity	400
Coal	1500
Trepel	50

GEO-ELECTRICAL MODELLING OF THE INVESTIGATED AREA

The geo-electrical models identify the different geological environments in the investigated area through parameters gained with direct interpretation of the geo-electrical investigations or indirectly while processing the obtained data [11]. The investigations are conducted through several measuring points in the investigated area. For every measuring point is produced two – dimensional curve that represents the dependency between the depth of examinations and the electrical resistance registered for that depth [12]. Depending of the electrical resistance that is registered in the geo-electrical models in this paper are made models of real and apparent electrical resistance.

While performing the geo-electrical investigations greater attention is dedicated on the level of underground water as well as its influence over the conductive properties of the geological structures. For precise estimation of the underground water influence it is necessary to accurately determine its depth or level in the geological complex as well as the porous features of the geological structures [13]. With increased porosity of the material greater amount of water is accumulated. That significantly increases the conductive properties, thus decreasing the electrical resistance of the structure [14].

GEO-ELECTRICAL MODEL OF REAL ELECTRICAL RESISTANCE

The curves of real electrical resistance are two dimensional half logarithmic curves where on the Y axis is marked the depth of examination expressed in meters (m) and on the X axis is registered the real electrical resistance that is manifested by the rock masses presented in Ωm [15]. The curves of real electrical resistance can be produced directly from field trials or synthetically with testing the different geological environments in laboratory conditions. The curves that are used in this paper are synthetic curves that are formed using the data from the mapped boreholes. The geo-electrical profile is a visual presentation of the geological structure presented thorough the real specific electrical resistance that is manifested by the different geological environments. On Figure 2 is presented the geo-electrical profile for the first profile line made from curves of real electrical resistance.

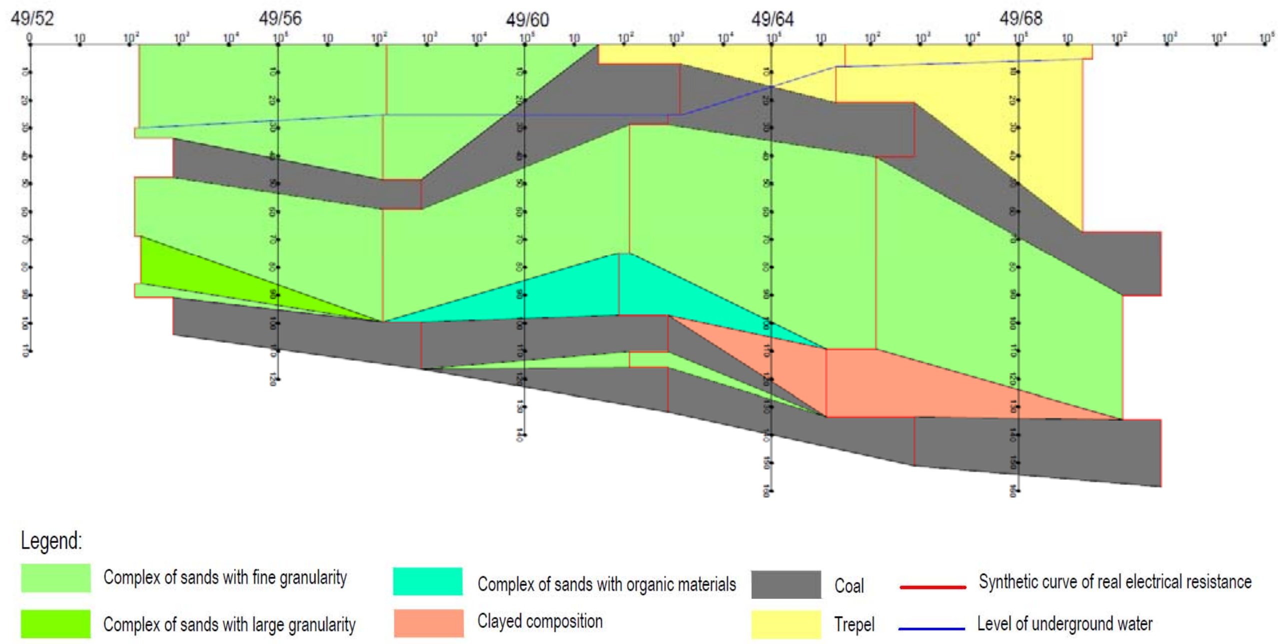

Fig. 2. Geo-electrical model of real electrical resistance

Through this modelling is determined the influence of the underground water to the geological structures. The conductive properties of the geological environments are directly obtained from the curves of real electrical resistance. The anomalies of the conductive properties are obtained directly without process of interpretation [16].

Whit the connection of the anomalies is determined the level of underground water in the geological complex. When correlating the obtained data with the geo-electrical properties and the geological data is determined the electrical resistance of the geological structures that are under the level of underground water. In the Table 2 are presented the geo-electrical characteristics of the geological structures that are under the level of underground water [17].

Table 2

Conductivity properties of submerged geological environments

Geological structures	Real electrical resistance (Ωm)
Complex of sands with fine granularity	120
Clayed composition	12
Complex of sands with organic materials	90
Complex of sands with large granularity	240
Coal	900
Trepel	30

GEO-ELECTRICAL MODEL OF APPARENT ELECTRICAL RESISTANCE

The models of apparent electrical resistance are two dimensional half logarithmic curves that on the X axis present the apparent electrical resistance for given depth that is registered on the Y axis. The apparent electrical resistance is the total electrical resistance that is manifested by geological complex and depends from the arrangement of measuring dispositive (the distance between the current and potential electrodes) as well as the real electrical resistance that depends from the conductivity properties of the geological structures [18]. The value of the apparent electrical resistance that is registered with Schlumberger arrangement [19] is calculated with the presented equation:

$$\rho_a = \frac{\pi a^2}{b}\left[1 - \frac{b^2}{4a^2}\right]R\,,$$

where:

a – distance from one current electrode and the center of the measuring dispositive,

b – distance between the two potential electrodes,.

π – constant with value 3.14,

R – total registered resistivity of the geological complex,

Under condition $a \geq 5b$.

Because of the spherical way of propagation of the electrical field, as well as the horizontally layered structure of the ore body, the different geological environments can be considered as parallel resistors [20]. According to that the total resistance of the geological structure that is composed out of n number of geological structures can be calculated through the following equation

Before going in a stage of modelling, for this type of curves, it is first necessary to interpret the registered values. First, the number of turns of the curve is determined which indicates the number of different geological environments. Any turns are sized according to X and Y and thus data on the thickness of the geological environment is obtained as well as the apparent electrical resistance that is manifested [21].

Using equation 2 and starting from the first geological environment, the specific electrical resistance of each geological environment is calculated inversely and according to that value the geological structure is identified [22]. The investigated environment is modelled on basis of the obtained data from the curves. On Figure 3 is presented the geo-electrical model of apparent electrical resistance.

From the interpreted data first are determined the anomalies of the conductive characteristics of the geological environments that define the registered level of underground water [23]. In the geo-electrical model the level of underground water is presented with solid blue line. The second step from the interpreted data for the real electrical resistance is identifying the different geological structures.

When comparing the geo-electrical model with the geological we can conclude that every geological environment is identified with the process of modelling. It is important to note that when using this methods of geo-electrical investigations the level of underground water can be defined with great precision where as some of the geological structures might get lost in the modelling [24].

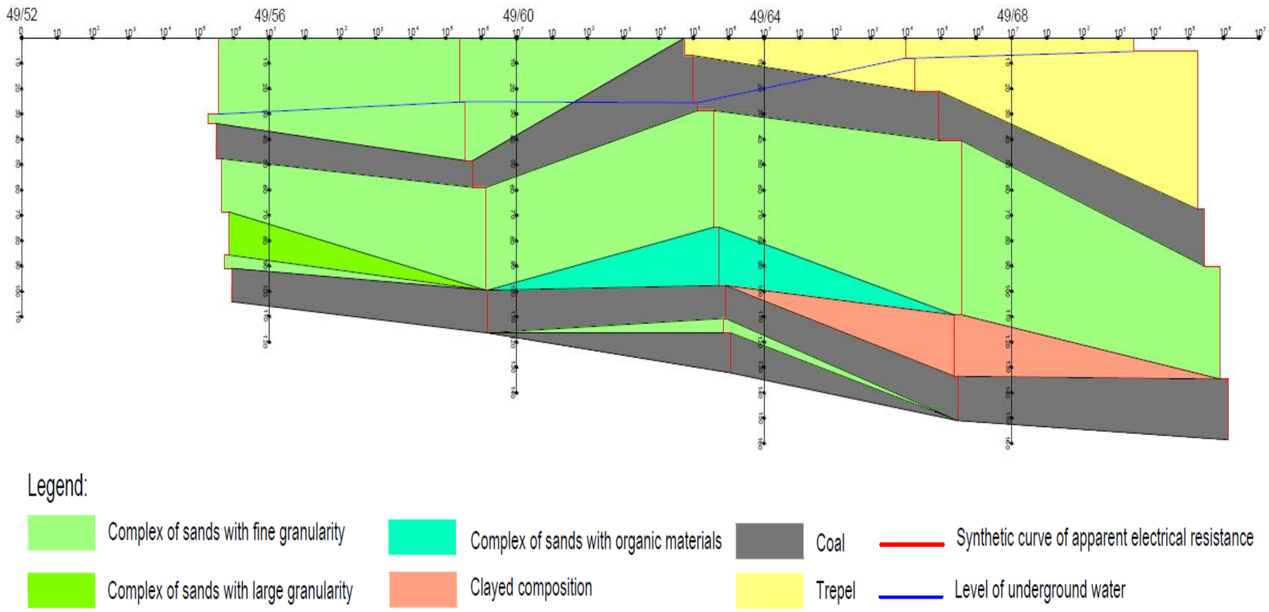

Fig. 3. Geo-electrical model of apparent electrical resistance

CONCLUSION

The surveys so far clearly indicate that the geo-electrical sounding is effective method for defining the under-surface geological structure as well as the level of underground water. In this paper is presented the process of development of geo-electrical models that can be used as etalons while researching similar geological areas. In the development of the models special attention is dedicated on defining the level of underground water and its effects on the conductive features of the geological structures.

The presented synthetically curves are good basis for further investigations of coal deposits in Republic of Macedonia and opening new mines for coal exploitation.The data that is obtained from the process of geo-electrical sounding complement the data from the mapped boreholes and the usage of this investigations can significantly reduce the number of necessary boreholes which will result with substantially lowering the costs of geological modelling. Depending on the purposes of the investigations the method of geo-electrical sounding can be applied independently or for greater efficiency in combination with other geophysical methods [25].

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Р е з и м е

ГЕО-ЕЛЕКТРИЧНИ МЕРЕЊА ВО СРЕДИНА СО ПРИСУСТВО НА ПОДЗЕМНА ВОДА

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Клучни зборови: Гео-лектрични испитувања; гео-електрично сондирање; синтетички криви; привиден електричен отпор.

Како средина за гео – електрично испитување е избран рудникот за јаглен "Суводол" кој геолошки е детално истражен со густа мрежа на картирани дупнатини. Слоевитата градба на рудното тело во испитуваната средина нуди поволни услови за примена на методата на гео – електрично сондирање. При изработката на моделите посебно внимание е посветено на нивото на подземна вода која има доминантно влијание при гео – електричните истражувања. Кривите добиени при гео – електричното сондирање се интерпретираат со решавање на директната задача. За добивање на поточни и поконкретни податоци при интерпретацијата на синтетичките криви потребно е добивање на прецизни податоци за специфичниот електричен отпор на картираниот материјал, а истото може да се постигне со тестирање на материјалот во лабораториски услови.